APPENDIX A - REPORTS

TRI - REGIONAL BOARD STAFF

RECOMMENDATIONS

FOR PRELIMINARY INVESTIGATION AND

EVALUATION OF UNDERGROUND TANK SITES

30 AUGUST 1991

Prepared by Staff of the

Central Valley Regional Water Quality Control Board

State of California

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

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California Regional Water Quality Control Board, Central Valley Region.
No policy or regulation is either expressed or intended.

APPENDIX A

To

TRI - REGIONAL RECOMMENDATIONS

- REPORTING -

The following document is for those interested in the investigation and cleanup of leaking underground storage tank sites. This letter is written direction prohibiting implementation of workplans or interim remediation at sites without Local Implementing Agency or Regional Board approval. Implementation of the Final Remediation Plan (or any Corrective Action) shall not begin until the Local Implementing Agency and Regional Board approve the Plan.

If you have any questions, please call (916) 361-5600 and request that an underground tank staff person assist you.

Gordon Lee Boggs
Underground Tank Program Coordinator

30 AUGUST 1991

Central Valley Regional Water Quality Control Board

APPENDIX A

TO
TRI-REGIONAL RECOMMENDATIONS

TABLE OF CONTENTS

REPORTING SOIL AND GROUND WATER CONTAMINATION PROBLEMS AT SITES

CONTAMINATED BY LEAKING UNDERGROUND STORAGE TANKS (LUST)

INTRODUCTION TO APPENDIX A

Appendix A is a companion document to the *TRI-REGIONAL BOARD STAFF RECOMMENDATIONS FOR PRELIMINARY INVESTIGATION AND EVALUATION OF UNDERGROUND TANK SITES*(Tri-Regional Recommendations). Appendix A is used for the Preliminary Investigation and Evaluation of sites as described in the Tri-Regional Recommendations. The Central Valley Appendix A expands the workplan/reporting provisions to include guidance for the investigation and remediation of soil and ground water problems. Figure #1 and Tables #1, #2, and #3 in the Tri-Regional Recommendations must be consulted for use with Appendix A.

This document is consistent with Chapter 16 Underground Storage Tank Regulations. It provides information necessary for tank owner (or designated responsible party) to prepare workplan, investigate the site, complete reports which identify the problem and to develop appropriate, cost-effective remediation measures. Regulation sections are designated as § 2652 (d).

PURPOSE - COST REDUCTION:

Appendix A's purpose is **to reduce the cost** of investigations to tank owners by providing them with sufficient information which they may use to instruct their consultant(s) on procedures for developing workplans and reports. The intent of the information is to avoid the question, **"Why is there never time to do the work, but always enough time to do it again?"**

When investigations of soil and/or ground water are necessary, tank owners are understandably concerned about their liability and the costs associated with the investigations and subsequent cleanup. Although we have no control over fees charged by consultants, laboratories, and drillers, or prices for pumps, towers, carbon units, or backhoes, etc., the costs of investigations can be reduced by using the information in Appendix A to develop workplans and reports. Complete workplans and reports reduce, significantly, the time required for review and approval by the regulating agencies. Additionally, time spent in the investigation phase can be reduced because the consultant, following these recommendations, is using the most direct, cost-effective, approach for developing appropriate remedial methods.

We do not believe that the best interest of the tank owner is served by prolonging the investigation and subsequent cleanup. Both inflation and changing laws and regulations will escalate costs to the tank owner. Also, the ability to construct on property or to transfer ownership will be severely restricted, usually by the lending institution, not the regulating agency.

FIGURE A-1 FLOW CHART

Figure A-1 displays a procedure for investigating and reporting for **Section III** fuel releases, **Case #3** non-fuel releases, and **known ground water** pollution sites. Throughout the process, **quarterly status** reports are required (see discussion on Page A-3).

The investigation/reporting process initially culminates in a Preliminary Investigation and Evaluation Report which leads to either Soil Remediation or Soil and Ground Water Remediation.

REPORTING

Both general and report specific requirements are discussed below. General requirements protect the interests of the tank owner and assure the regulating agencies that commitments have been made. These include Tank Owner Commitment, comprehensive requirements and monitoring well installation. Report specific requirements guide the tank owner in preparing the report phase for LIA and Regional Board review.

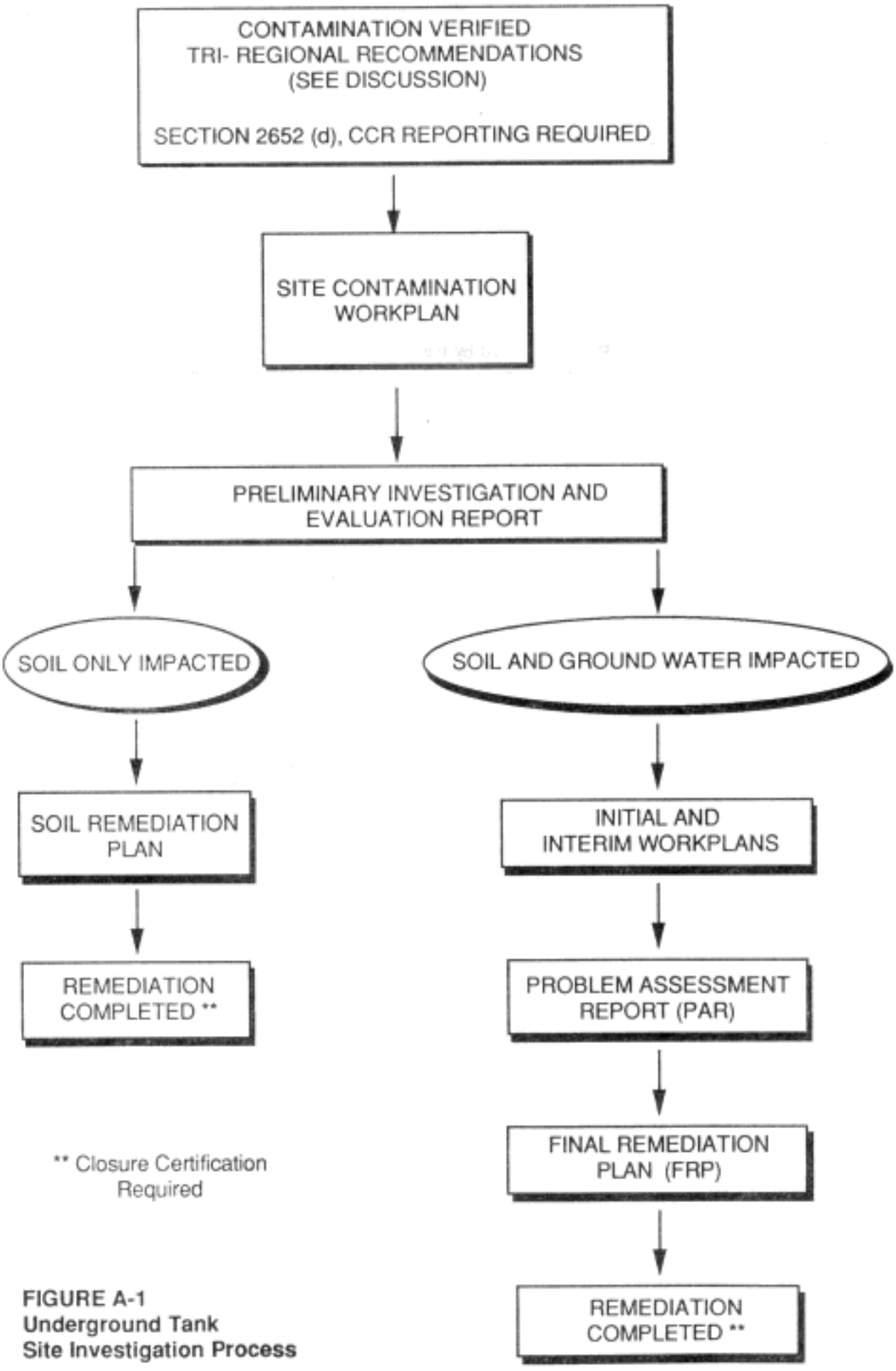

FIGURE A-1
Underground Tank
Site Investigation Process

All reports **and workplans** prepared for the Regional Board are to be submitted to both the Regional Board and LIA for review and approval. Interim remediation **shall not commence** without LIA or Regional Board approval.

GENERAL REQUIREMENTS

Tank Owner Commitment - A cover letter from the tank owner (or Responsible Party designated by the tank owner) is to be submitted with all reports and workplans stating:

- Agreement or disagreement with the conclusions and recommendations in the report or workplan;
- The accuracy of the report and that Local Implementing Agency or Regional Board guidelines have been followed;
- The time lines and projected schedule for the next phase of investigation; and
- Whether (and why) a meeting is requested to discuss options.

Comprehensive

- Reports and workplans are to have pagination.

- Time schedules are to be included showing weeks and months to completion with key steps shown.

- Each report is to summarize previous reports, as necessary and available, to assure that it may be reviewed independently. It is not acceptable to reference a graph, table, borehole log, etc., in a another report (at times not even available).

- Technical assistance for completing reports and workplans may be provided by environmental consultants in the private sector. Reports, documents, and plans which contain engineering, geology, and/or geophysical information must be prepared under the direction of properly licensed individuals in the State of California (Sections 6735, 7835, and 7835.1 of the California Business and Professions Code). Responsibility for the technical information is indicated by the signature and/or stamp of the seal of the licensed individual. More than one signature and/or seal may be required where more than one professional specialty is included in the technical document submitted.

- All borehole and monitoring well logs, excavation procedures, and soil/ground water samplings are to be certified by a Registered Geologist, Certified Engineering Geologist, or Registered Engineer. (This assures the regulatory agencies of the integrity of the work and protects the tank owner's interests.) All subsurface geologic data from boreholes, monitoring wells, trenches, etc. are to be displayed on geologic cross sections.

Monitoring Well Installation: Individual well diagrams are to represent the completed well accurately and show or describe:

- Types and quantities of materials placed in the borehole;
- Placement method of annular space materials; e.g. tremmie pipe, poured from the surface, not placed, etc.;
- Detail of the location of screening, bentonite seal, sanitary seal, etc.;
- Nominal inner diameter (ID) and outer diameter (OD) of the auger and casing;
- Copies of drillers and/or geologists logs for drilling and construction;
- Any field notes from development and purging of the well and descriptions of difficulties encountered during drilling; and
- Type of rig equipment used for well construction, development method, volumes purged from the well and names and license numbers of the company, geologist and driller identified.

All report maps are to be prepared as follows:

- All maps oriented with north up on the page.
- A scale proportional to map size included, e.g. |___5___|___5___| = 10 feet.
- Show all above ground structures including canopies and power lines.
- Indicate buried pipes, tanks (with each tank labeled for content), leachlines, utilities, etc.

Quarterly Status - §2652(d)

Tank owners, operators, or permittees are to report at least quarterly to the Local Implementing Agency and the Regional Board until investigation and cleanup of the site is deemed adequate (more frequent reporting compliance may be required by the Local Implementing Agency or the Regional Board). These reports are to show the:

- status of investigation and cleanup activities including the results of all investigations implemented to date;
- proposed continuing or next phase of investigation;
- method of cleanup proposed or implemented to date;
- time schedules for the completion of the investigation of the site and remediation;
- method and location of disposal of the released hazardous substance and any contaminated soil, ground water or surface water;
- manifest required for transport of hazardous substances;
- monitoring well data including ground water elevation, pH, conductivity, temperature and gradient;
- tabulated analytical results of ground water or soil sampling;
- a site map showing the "zero line" of contamination, if known, and changes in analyses and gradient measurements over the last quarter;
- tabulated data for all monitoring wells including ground water elevations collected to date;
- a site map delineating ground water elevation contours based on recent data; if the site is in remediation, define the zone of capture for any extraction well(s) on the contour map;
- tabulated analytical results from all previous sampling events including laboratory reports for the most recent sampling event and chain of custody documentation;
- site map delineating contamination contours for soil and ground water based on recent data;
- tank owner commitment letter;
- the quantity of ground water, vapors, and hydrocarbons removed (in gals., cu. ft., and lbs., respectively), during the reporting period and cumulative to date;
- times and dates equipment was not operating, cause of shutdown, and a corrective action plan to insure similar shutdowns do not reoccur (proposed corrective actions are to be completed within 30 days of the system shutdown);
- timelines for activities currently underway or proposed. Compare new timelines to those previously submitted with a written explanation for changes; and
- estimates of the quantity of contamination remaining in soil and ground water, and time for completing remediation.

The information may be submitted as a letter with a site map to the regulating agencies.

SPECIFIC REQUIREMENTS

SECTION III INVESTIGATION

Once a tank has been removed, there may be significant soil problems which can not be resolved by a "scoop and run" cleanup of minor overspills, but remain to be identified and remediated. To pursue a successful site remediation plan, the lateral and vertical extent of soil contamination must be defined.

The preliminary investigations are critical. Failure to provide the information because the work was done impatiently or improperly is expensive because it requires backtracking and impedes subsequent

investigations. The information is needed for the LIA and Regional Board to make a proper decision.

As shown on Figure A-1, the investigations are procedural and linked. Information developed for one is included in the next phase. The **Site Contamination Workplan (SCW)** prepares basic information required for any subsequent work and may be sufficient for the LIA to certify closure. The **Preliminary Investigation and Evaluation Report (PIER)** determines whether soil only is impacted or if ground water also must be investigated. Once the LIA decision is made, based upon a complete PIER, the tank owner will be informed to proceed with soil remediation by completing and implementing the **Soil Remediation Plan (SRP)** or to continue the investigation. If ground water is found to be impacted a **Problem Assessment Report (PAR)** is needed to define the problem area and propose remedial measures. The **Final Remedial Plan (FRP)** incorporates the accepted plan, time schedule for implementation and operation, and a contingency plan to correct potential problems.

Reports are to be submitted to the LIA for approval, and to the Regional Board for incorporation in the Underground Tank data base. Where extensive soil problems exist, the reports also may be reviewed by the Regional Board.

Site Contamination Workplan (SCW) -§2832(c)(d), §2653(c)

The workplan is used to develop preliminary information to direct subsequent investigation(s).

Background

- Name and address of site, tank owner, and contact person, if different.
- Area map showing site location relative to nearby landmarks such as rivers, highways, urban or industrial areas, etc. (approximate scale equivalent to a USGS topographic map or road map).
- Scale drawing of the site showing adjacent streets and buildings, septic tanks and leachfields, and underground utility lines (approximate scale: 1 inch = 20 feet).
- Layout of all tanks and piping systems on the property, with each tank labeled for content.
- Results of tank tests and summary of other initial site work completed.
- Estimates of the quantity and composition of liquid leaked into the environment and how quantified.
- Information on local topography, geology, nearby streams, and depth to ground water.
- Date of tank(s) removal and condition of the tank system.
- History of tank repair.
- Tank testing results, dates and inventory reconciliation methods since 1 January 1984.
- Copy of unauthorized release report form.
- Description of liquid or solid wastes removed, including copies of all manifests.
- History of leaks, spills and accidents at the site involving the tank system.
- Previous subsurface on-site or adjacent site work including:

    - Table of soils and/or water analyses
    - Soil sampling procedures used
    - Soil stratigraphy in excavation or borings
    - Depth to ground water, if encountered
    - Description of any unusual problems encountered

- History of site and tank use.
- Proposed sampling locations and methodology with time schedules for completion of the work and a plan for disposal of drilling spoils.

Soil Investigation - §2652(c), 2653, 2654

Describe or identify the method or technique for:

- Determining the extent of contamination within the excavation;
- Sampling;
- Number of boreholes, location, sampling depth, etc.;

- Laboratory analyses;
- Soil classification system;
- Boring/Drilling;
- Soil gas survey, if planned;
- Subcontractors; and
- Quality Assurance plan for field testing.

Ground Water Investigation

Monitoring and observation well placement is to adhere to Tri-Regional Recommendations; construction of the well is described in the LUFT document and may be regulated by the LIA. If a single monitoring well is placed in the verified downgradient direction, the veri-fying data is to be submitted with the workplan. The workplan is to include:

- Map, to scale, showing the location of nearby wells;
- Construction diagram for wells;
- Drilling method and decontamination between drillings;
- Well diameters;
- Date of drilling;
- Casing type;
- Seal type and depth;
- Development method and criteria for selection of the method;
- Disposal plans for cuttings and development water;
- Survey plans for the wells;
- Water sampling plans;
- Water level measurement procedure;
- Well purging procedure and purge water disposal plan;
- Sample collection procedures;
- Free Product measurement method;
- Analytical methods to be used; and
- Quality Assurance plan including Chain of Custody procedures.

Upon approval of the workplan to define the soil contamination (and contaminant vapor plumes if appropriate), the tank owner or their consultant must obtain the necessary permits from the LIA. Work on the site is to continue until the soil problem is completely defined.

Preliminary Investigation and Evaluation Report (PIER) - §2645, §2833

Information developed for this report will determine whether a **soil only** or a soil **and** ground water remediation must be considered. The PIER is to contain:

- Basic information developed from the SCW (summarized);
- The problem area is to be accurately delineated on maps and cross sections to scale that depict the lateral and vertical extent of soil contamination, and lateral and vertical extent of vapor plume(s). Cross sections must include soil stratigraphy based upon boreholes, trenches, monitoring wells, or any other supporting information;
- Tables summarizing analytical data and methodologies used to collect and analyze the samples;
- Depth to ground water; and
- Ground water quality.

If a soil only case is indicated, proceed to the **Soil Remediation Proposal**. If soil and ground water are impacted proceed with the **Problem Assessment Report**.

SOIL REMEDIATION

Soil Remediation Proposal

At this time the tank owner is to submit a SOIL REMEDIATION PROPOSAL which contains information that summarizes the data and develops alternatives for the tank owner and LIA to consider. The SRP content is as follows:

- A complete description of the remedial steps proposed to clean up the soil contamination.

- A complete description of the remedial steps proposed to clean up contaminant vapor plumes.
- The volume of soil to be remediated.
- Location and boundaries of the remediation area.
  Geology and depth to ground water at the remediation area.
- Measures to be taken to prevent any water quality impacts during remedia-tion.
- Expected concentrations of contaminants after remediation.
- Final disposition and location of soil from both the remediation process or drilling spoils.
- Whether there is a need for any monitoring wells and continued ground water sampling and analysis during or after remediation of the soil will be determined based on the amount of contamination left in place and the depth to ground water.

Upon completion, the SRP is submitted to the LIA for review and approval. Negotiations between the tank owner and LIA may change the proposal depending on the amount and extent of contamination discovered during the site investigation and any residual contamination remaining on-site which may contribute to future nuisance conditions.

EXAMPLE: When all soil contamination has been removed or it has been determined by the LIA that any residual material **cannot** impact ground water, the site can be closed and certified.

A summary of the site assessment and soil remediation completed at a LUST site is to be sent to the Regional Board for incorporation into the Regional Board data base and filing system.

GROUND WATER AND SOIL REMEDIATION

When ground water has been shown to be contaminated as a result of a tank leak, the site investigation is to proceed in phases. Each phase is to be a complete entity, with a report completed according to the schedule below and submitted by the tank owner to the LIA and Regional Board for review, comment, and approval. If the report lacks prescribed data, as described below, such as detailed maps, it may be returned to the tank owner for completion prior to resubmittal for regulatory review. The reports should be sufficient to describe the problem and suggest remedial actions that would mitigate or eliminate the ground water and soil problems.

The intent is to provide a consistent format for the tank owner; so, regardless of who bids on, or completes a phase, the reported information will be in a format the tank owner will understand and be assured that the regulatory agencies are getting the information they need to make a decision on the site.

The reports are:

1. **PIER** - See Page A-5.

   Interim Workplans are submitted until the lateral and vertical extent of contamination is determined. The proposed workplans may be submitted with the quarterly status reports.

2. A **Problem Assessment Report** (PAR) describes the lateral and vertical extent of a problem, and proposes mitigative or remedial actions to clean up a site, and;

3. The **Final Remediation Plan** (FRP) is to propose acceptable activities to the regulatory agencies and tank owner, implementing work to be completed on a time schedule.

Initial Workplan

The initial workplan preparation of the PAR constitutes a "blanket" workplan to cover contingencies of future work. As such, safety plans, QA/QC, and sampling and analytical procedures are constants and do not require repeating in subsequent workplan addenda unless changed. Note that soil contamination should be defined at this time. If not

this workplan is to include soil work as described in the Site Contamination Workplan (See page A-4).

Following is information to be included in the workplan (although somewhat redundant, it is repeated for emphasis):

- Name and address of site, tank owner, and contact person, if different.
- Copy of unauthorized release report form.
- Area map showing site location relative to nearby landmarks such as rivers, highways, urban or industrial areas, etc. (approximate scale equivalent to a USGS topographic map or auto club map).
- Detailed site map showing:
  - layout of all tanks and piping systems,
  - with each tank properly labeled for content,
  - adjacent streets and buildings,
  - septic tanks and leachfields,
  - underground utility lines including electrical, telephone, water and sewer, canopies, etc. (approximate scale 1 inch = 20 feet).
- History of site and tank use.
- Date of tank(s) removal and condition of the tank system.
- History of tank repair.
- Description of liquid or solid wastes removed, including copies of all manifests
- Results of tank tests, dates and inven-tory reconciliation method, or initial site work completed since 1 January 1984.
- History of leaks, spills, and accidents at the site involving the tank system.
- Tables summarizing preliminary soil and ground water data.
- Estimates of quantity and composition of liquid leaked into the environment and how quantified.
- Information or figures for local topography, geology, soil stratigraphy, nearby streams, and depth to ground water.
- Proximity of private, municipal, and irrigation wells within 2000 feet of the site.
- Proposed sampling locations and methodology and disposal plan for drilling spoils and purged water.
- Time schedules for completion of work.

- Ground Water Investigation

  Monitoring and observations well placement is to adhere to Tri-Regional Recommendations; construction of the well is described in the LUFT document and may be regulated by the LIA. If a single monitoring well is placed in the verified downgradient direction, the verification data is to be submitted with the workplan. The workplan is to include:

  - Map, to scale, showing the location of nearby wells;
  - Construction diagram for wells;
  - Drilling method and decontamination between drillings;
  - Well diameters;
  - Date of drilling;
  - Casing type;
  - Seal type and depth;
  - Development method and criteria for selection of the method;
  - Disposal plans for cuttings and development water;
  - Survey plans for the wells;
  - Water sampling plans;
  - Water level measurement procedure;
  - Well purging procedure and purge water disposal plan;
  - Sample collection procedures;
  - Free Product measurement method;
  - Analytical methods to be used; and
  - Quality Assurance plan including Chain of Custody procedures.

Discussion of Initial Workplan

All permits are obtained from the LIA. Starting and sampling dates are to be provided to both the LIA and Regional Board at least 48 hours in advance of each activity.

NOTE: If the LIA has not adopted monitoring well construction specifications or lacks jurisdiction for drilling permits, these plans and proposals, and any subsequent requests, **must** be submitted to the Regional Board for review and approval.

In order for our review to proceed and the tank owner to be back in business as soon as possible, a concise, complete report is necessary. Time and staff restrictions do not allow the regulatory agencies to interpret pages of raw data and attempt to explain them to the tank owner.

Workplan Addendum

If work proposed in the Initial Workplan does not completely define the extent of soil and ground water contamination, the tank owner may submit a one or two page workplan addendum(a) (with site map) briefly detailing work to date, sampling results and proposed additional work. This data may be submitted with the quarterly status report. The extent of contamination is to be completely defined in a Problem Assessment Report prior to proceeding with a Final Remediation Plan.

PROBLEM ASSESSMENT REPORT (PAR) - §2835

This report is to summarize the PIER and delineate the problem accurately by including:

- Tables summarizing analytical data such as compound concentrations found in soil and ground water, and sample depth.
- Figures delineating horizontal and vertical extent of ground water contamination plume(s) and zones of soil contamination as appropriate.
- Figure(s) delineating extent of vapor plumes (if appropriate).
- Contaminated aquifer ground water gradient and regional gradient based upon recent data on depth to ground water.
- Soil stratigraphy and cross sections based upon boreholes, monitoring wells, trenches, and supporting geological mapping logs.
- Map showing local wells, buildings or utilities impacted or potentially threatened.
- Defined extent of soil and ground water contamination, the lateral and vertical "ZERO LINE" on site maps and cross sections for both soil and ground water.
- Floating product found--depth and extent.
- Preliminary pumping test and soil analysis results as necessary to investigate the remediation alternatives.

Using preliminary field tests and/or lab pilot studies, investigate and submit proposals and costs for at least:

a. Excavation
b. On-site soil aeration
c. Off site soil treatment
d. Landfilling
e. Soil venting
f. Ground water extraction and treatment by aeration, carbon filtration, pump to sewer, etc.
g. Biodegradation--soil and ground water
h. Physical containment
i. Chemical neutralization
j. Incineration
k. No action
l. Other (new technology)

With minimal investigation and explanation, some alternatives may be eliminated as simply not feasible for the site. For instance, soil venting is practical in sandy soils but difficult to justify for tighter clay soils where excavation and removal or excavation with bioremediation may be a better consideration.

Note: If disposal in a landfill, sewer line, air stripping, etc., are proposed, the consultant must include assurances from each appropriate regulating agency that the activity is acceptable. **It is not acceptable to submit a remedial alternative that can not be implemented and then attempt to use the report to justify its implementation.**

Interim Remediation: §2655, §2832

At times the tank owner may want to install equipment to remove "free product" or initiate minor soil cleanup before approval of a remedial plan. Such action may be warranted but is always at the owner's risk and may impede, or increase the costs of, the final action required. **Interim remediation shall not commence without LIA or Regional Board approval.**

Discussion of the PAR

During problem assessment, while the drilling equipment is on-site, sufficient soil boreholes and monitoring wells should be completed, as necessary, to define the soil and ground water problem. As work progresses, more monitoring wells and boreholes than those originally suggested will undoubtedly be required.

When new permits for borehole and/or monitoring wells are requested, **a letter requesting the change and a site map showing the proposed locations of the boreholes and/or monitoring wells is to be submitted for approval to both the LIA and the Regional Board.** The map must include the line of demarcation for both the soil and ground water contamination found in the latest and previous soil and ground water analyses. The proposed **time schedules** of soil and ground water sampling, and ground water gradient determination are to be included.

If a due date cannot be met, the tank owner (or designee) must request a due date extension in writing. The request is to include a proposed due date and complete justification for the extension and the new date requested. For instance, off-site drilling may be required, which frequently causes project delays while negotiating with off-site property owners for permission to drill on their property. If the delay would cause the tank owner to exceed the due date, an extension must be requested immediately. Regional Boards and LIAs will provide assistance in obtaining permission to drill off-site, thereby avoiding lost time for completing the site investigation.

As part of the PAR process, remedial measures are to be investigated for their feasibility at the site. All are to be addressed. Where subsurface Central Valley Hydrogeology is considered Hydraulic Conductivity Testing will be needed to design an appropriate, cost effective remediation system. Where it has not been considered, it is Regional Board experience that the systems often can be inefficient, ineffective or both; thereby raising costs to the tank owner. Therefore, data are to be produced in accordance with the following:

CENTRAL VALLEY HYDROGEOLOGY AND HYDRAULIC CONDUCTIVITY TESTING

With few exceptions in the Central Valley, ground water contamination problems resulting from leaking underground storage tanks are found in water table (unconfined) aquifers. As such, investigations to define the extent of contamination and design of the remediation system(s) will require knowledge of the subsurface hydrogeology. To acquire the hydrogeologic information, construction of soil borings, monitoring wells or even trenches can be used to develop limited characterization from which judgments can be derived.

Subsurface testing will provide ESTIMATES 1) to describe subsurface conditions, 2) to suggest a method for remediation and 3) to predict how effective the process might be for completing the remediation. Often these estimates for remediation are created by analytical or numerical computer models based upon the physical field measurements of the aquifer. The accuracy of a remediation system is confirmed by observations during the operation and maintenance of the system with competent and consistent groundwater sampling for hydraulic conductivity (the higher the conductivity, the better the aquifer conducts water), released substance analysis, and gradient capture.

AQUIFER TESTS FOR HYDRAULIC CONDUCTIVITY

Aquifer tests are used primarily to derive transmissivity (T), storativity (S), and hydraulic conductivity (K). Aquifer tests also help predict the radius of influence for individual or multiple wells. The results from a properly conducted aquifer test provide the most important tool for determining the performance characteristics of ground water extraction wells, hydraulic parameters of the aquifer, and the zone of capture achievable from the extraction point(s).

The goal of conducting an aquifer test is to obtain sufficient information to design an appropriate, efficient remediation system. In some instances it may be possible to implement a remedial action plan based on "**order-of-magnitude**" or "**ballpark**" estimates of aquifer parameters. However, a remediation system based on these criteria may require significant modification after the performance has been evaluated. These modifications may result in significant added expense to the tank owner which would have been avoided with adequate aquifer testing in the pre-design phase.

AQUIFER PUMPING AND "SLUG" TESTS: Fundamentally, aquifers are tested by pumping in one well while water levels are checked in several surrounding wells to determine the effect of the pumping in the area. In slug tests a known weight (slug) is placed in or taken out of a well and water level changes measured with no pumping. The resulting data are integrated into computerized models which help estimate the hydraulic conductivity of the substrate.

Selection of a specific test may result from a problem of disposing of the pumped ground water, or aquifer conditions. Long-term aquifer pumping tests require continual readings over a period of 24 to 72 hours by staff or in-well transducers. Staff time can be expensive and transducers are not cheap. However, today, consulting firms conducting ground water work should have transducers as part of their equipment arsenal. Some water table aquifers, especially in parts of the Central Valley, have low hydraulic conductivities, so a slug test in several wells may be used to generate data to approximate aquifer parameters.

Aquifer Pumping Tests: The two primary pumping tests are the constant-rate and step-drawdown. These tests are somewhat expensive because staff time is required to conduct continual, on-site well measurements and maintenance of pumps and equipment needed for the observation wells. However, long term pumping tests of the aquifer would provide the most reliable information for designing remediation systems.

CONSTANT-RATE pumping tests allow direct measurements of the pumping rate influence, over time, on water levels in surrounding monitoring wells. Before conducting a constant-rate pumping test, the well must be developed and the water level in the aquifer allowed to reach static (non pumping) conditions. During the long term test, the wells must be pumped at a constant rate for 24 to 72 hours, depending upon aquifer characteristics. (Shorter pumping times provide an "order of magnitude" measurement.) Accurate measurement of drawdown in the pumping well and observation wells must be taken at prescribed intervals throughout the duration of the test. It is extremely important to measure and analyze well recovery data where "Q" (flow rate) is considered constant.

The STEP-DRAWDOWN test involves increasing the pumping rate in steps at regular intervals. The transmissivity and storage coefficients are calculated from the data obtained during the first step. Unfortunately, the validity of these values for application in the remediation system may be doubtful because they are based on data taken over a relatively short time. The real value of a step-drawdown test is that it allows calculation of the specific capacity of the well so that the efficient well yield can then be derived. The step-drawdown pumping test is especially useful when the transmissivity of the aquifer is unknown and in slow producing aquifers. The pump is operated at a set rate to determine the influence of that rate on the aquifer and then the pumping rate is increased until an equilibrium is

reached with the aquifer recharge into the pumping well.

In CONFINED AQUIFERS the zone of influence spreads rapidly because there is no actual dewatering of the aquifer; rather there is a pressure reduction which occurs outward from the well. Thus a 24 hour period of pumping is usually sufficient to record enough reliable data from the confined aquifer.

In WATER TABLE AQUIFERS (unconfined) the pumping test **may** require up to 72 hours because of the slow percolation of water in stratified deposits commonly found in Central Valley alluvial soils. This time may be reduced if equilibrium conditions are established or, as in many cases, the water table is less than 50 feet below the ground surface. In no event should aquifer tests be terminated prematurely; because the limited data collected may not reveal the true nature of the aquifer in all cases, the analysis must be appropriate to field conditions.

SLUG TEST: This procedure is particularly appropriate for small-diameter piezometers or monitoring wells. It is a simple, quick and inexpensive test to estimate the horizontal hydraulic conductivity at a specific location. Advantages for its use are (1) where pumping large volumes of contaminated water may require treatment or permit(s) for discharge or (2) when low permeability formations preclude pumping large volumes of water. Because only well specific data are obtained, the application of slug test data to the aquifer is limited because they are not representative of the entire aquifer. Filter pack effects radial variances in permeabilities of the aquifer and clay smearing of the borehole during construction are all limitations of the method. Each monitoring well in the system is to be tested and the results defined prior to designing a remediation system.

Equations for slug tests on partially or completely penetrating wells in unconfined aquifers are available. The hydraulic conductivity of an aquifer near a well can be calculated by slug tests using **either falling or rising water level tests**. For slug tests the water level in the well is suddenly changed and the rate of fall or rise of the water level is measured. The more permeable the aquifer, the faster water levels change. The change in the water level can be measured with fast-response pressure transducers and strip chart recorders. The hydraulic conductivity of the portion of the aquifer tested by the slug test depends on the geometry of the flow system, specifically, the well screen length, the thickness of aquifer penetrated by the well, and the radial distance between the undisturbed aquifer and the well center.

HYDROGEOLOGIC DATA PRESENTATION

Regardless of the testing system used or the calculations performed, all refined data, calculations and resulting conclusions are to be submitted in the Problem Assessment Report. All assumptions and rationale for using the selected method for evaluating the data also are to be discussed and submitted.

Following the completion of appropriate ground water and soil gas measurements to prepare a proper liquid and/or gaseous phase remediation system, the data must be transformed to define the area of contamination. Based upon the areal extent of the problem and the pumping tests, the receptiveness of the soil and aquifer for remediation can be estimated by direct calculation or predicted by modeling. The results of the prediction help to define the zone of influence of the remediation system. The above factors can be used to construct an adequate soil or ground water pumping and remediation system. However, appropriate modeling programs are to be used to predict subsurface conditions. For example, confined aquifer tests are inappropriate for interpreting unconfined, water table aquifer conditions.

Hydraulic conductivity testing data and modeling programs used to predict the zones of influence and capture are to be submitted in the Final Remediation Plan. The data and modeling program will be verified by the regulating agency.

After the report has been submitted to the LIA and Regional Board for review, all data should be included and no further investigation required by the consultant. (Should more data be needed, it will be

necessary to inform the tank owner by letter that the PAR is incomplete and a revision is needed before a remedial action plan can be implemented.) A meeting with the tank owner and consultant may be required to "iron out" any problems in the report. (With the objective to reduce meetings and thereby costs, this would be one of our few meetings; other contacts should have been by correspondence, telephone, or on-site investigations.)

Upon acceptance of the PAR by the regulatory agencies, a letter will be sent to the tank owner which includes details of the procedure(s) agreed upon by the agencies and tank owner. The consultant can then prepare the Final Remediation Plan for approval by agencies.

FINAL REMEDIATION PLAN (FRP) - §2835

The FRP is based upon the PAR assessment, discussions and negotiations between the Regulatory Agencies and the tank owner and their consultants, and results of the final field and laboratory tests. **Implementation of the Final Remediation Plan (or any Corrective Action) shall not begin until the LIA and Regional Board approve the plan.**

The FRP is to include:

- Results of hydrogeologic measurements and predictions.
- Results of final field tests and/or laboratory pilot studies.
- Remedial activity details such as number of recovery wells, placement, pumping rate, soil to be excavated, layout of vent lines, disposal of wastes, biodegradation rates, etc.
- Discussion of implementation, including a phased schedule if necessary.
- Dates for beginning work stages.
- Site plan with proposed work areas defined.
- Soil Aeration On-site requires a complete description of the treatment method

  In-situ
  - Soil stratigraphy and geology
  - Subsurface utility layout
  - Layout of piping system
  - Depth of piping
  - Placement of pumps, blowers, remediation system
  - Proposed remediation system: e.g., Air Tower, Granulated Activated Charcoal, thermal decomposition, internal combustion engine, etc.
  - Permits required with time schedule for applications and local turnaround
  - Contingency Plan for system failure

  On-Site
  - Volume of soil to be treated
  - Treatment method, e.g., aeration, bioremediation, chemical, etc.
  - Volume and rate of turning
  - Containment or cover required
  - Wet weather contingency plan

- Ground Water Treatment remediation plans are to include:

  - Zero Line definition or projection
  - Aquifer Pumping Test results and projections
  - Proposed Remediation system, e.g., Pump and aerate, spray, pond, thermal incineration, Granulated Activated Charcoal filtration, etc.
  - Proposed discharge, e.g., sewer, storm drain, surface water, land, reinjection, etc.
  - Permits required with time schedule for application and turnaround time
  - Feasibility studies conducted with results tabulated
  - Calculations used to determine the efficacy of the system submitted for verification

- Security/Safety measures for excavation on-site, contaminated soil piles, pumps and treatment systems.

Discussion of FRP

After approval of the Plan and time schedule, work may proceed. Should delays occur or extensions of the time schedule be needed, such requests, with supporting documentation, are to be made by letter to the Regional Board and LIA. Quarterly reporting will continue.

Closure

Upon successful completion of the FRP activities, and a petition by the tank owner, a letter will be prepared by the Regional Board describing regulatory conditions of concern to the Regional Board or LIA, such as deed restrictions, long term monitoring, alternative drinking water sources, etc. The letter also will certify or confirm the conditions remaining at the site.

RECOMMENDED MINIMUM VERIFICATION ANALYSES (MVA)

Verification analyses for organic chemicals are conducted in laboratories certified by the California Department of Health Services. The MVA are based upon the organic chemicals and mixtures known to be found in underground tanks, but are not all inclusive; therefore, they tend to have a broad scope. Laboratory analyses are needed to determine what substance (qualitative) and how much (quantitative) is present in soil and ground water. The analyses help determine the lateral and vertical extent of contamination ("zero"line") which is used to develop an efficient and cost effective remediation process. More critically, analyses determine whether remediation is satisfactory (low level analyses required) and the site "cleaned" and stabilized.

To determine that the laboratory is providing satisfactory service, the in Quality Assurance/Quality Control (QA/QC)plans for the laboratory must be considered. Quality Assurance includes the policies which direct the laboratory. Quality Control is the physical processing of the sample and is critical for precise and accurate analyses. Precision and accuracy, paramount to analytical work, are increased by improved by QA/QC; however, analytical costs also may increase.

The cost/analysis table below shows cost ranges for laboratories with offices in California, but is not correlated to QA/QC. Based on Regional Board experience, some of our consistently accurate laboratories with good QA/QC have analytical charges at or near the average cost for the analyses listed. Over the past four years average costs have increased about three dollars ($3.00) for BTX&E and TPH-Gasoline, but have decreased eleven dollars ($11.00) for TPH-Diesel in soils while QA/QC generally has improved.

Problems beyond the control of laboratories which raise detection levels of chemicals include matrix problems such as multiple interfering substances in the soil or water sample, samples that were taken improperly by the field worker, or that the sampling team QA/QC was inadequate. These are to be reported by the laboratory as part of the report to the tank owner.

Procedures to improve detection levels that are within the control of the laboratory include, but are not limited to: dedicating detectors, using columns defined for the purpose, increasing sample size, changes in extraction procedures, solvent modifications, and increased staff training.

COST/ANALYSIS TABLE
(October 1990)

ANALYSIS	COST		
	Range	Avg	Median
BTX&E			
Water (602)	$75-$165	$109	$110
Soil (8020)	$65-$200	$119	$120
TPH-Gasoline			
Water (GCFID)	$60-$150	$103	$105
Soil (GCFID)	$60-$150	$103	$105
TPH-Diesel			
Water (GCFID)	$60-$150	$100	$100
Soil (GCFID)	$60-$150	$100	$100